NA60 results on p_T spectra and the ρ spectral function in In–In collisions

J Seixas[1] **(for the NA60 Collaboration**[12])[13]

R Arnaldi[2]**, R Averbeck**[3]**, K Banicz**[4,5]**, J Castor**[6]**, B Chaurand**[7]**, C Cicalò**[8]**,
A Colla**[2]**, P Cortese**[2]**, S Damjanovic**[4]**, A David**[1,2]**, A De Falco**[8]**, A Devaux**[6]**,
A Drees**[3]**, L Ducroux**[9]**, H En'yo**[10]**, A Ferretti**[2]**, M Floris**[8]**, A Förster**[4]**,
P Force**[6]**, N Guettet**[6]**, A Guichard**[9]**, H Gulkanian**[11]**, M Keil**[1,4]**, L Kluberg**[7]**,
C Lourenço**[4]**, J Lozano**[1]**, F Manso**[6]**, A Masoni**[8]**, P Martins**[1,4]**, A Neves**[1]**,
H Ohnishi**[10]**, C Oppedisano**[2]**, P Parracho**[4]**, P Pillot**[9]**, G Puddu**[8]**,
E Radermacher**[4]**, P Ramalhete**[4]**, P Rosinsky**[4]**, E Scomparin**[2]**, S Serci**[8]**,
R Shahoyan**[1,4]**, P Sonderegger**[1]**, H J Specht**[5]**, R Tieulent**[9]**, G Usai**[8]**,
R Veenhof**[1,4] **and H K Wöhri**[8]

[1] LIP, Lisbon, Portugal
[2] Univ. di Torino and INFN, Italy
[3] SUNY Stony Brook, New York, USA
[4] CERN, Geneva, Switzerland
[5] Univ. Heidelberg, Heidelberg, Germany
[6] LPC, Univ. Blaise Pascal and CNRS-IN2P3, Clermont-Ferrand, France
[7] LLR, Ecole Polytechnique and CNRS-IN2P3, Palaiseau, France
[8] Univ. di Cagliari and INFN, Cagliari, Italy
[9] IPN-Lyon, Univ. Claude Bernard Lyon-I and CNRS-IN2P3, Lyon, France
[10] RIKEN, Wako, Saitama, Japan
[11] YerPhI, Yerevan, Armenia

Abstract

The NA60 experiment at the CERN SPS has studied low-mass muon pairs in
158 AGeV In–In collisions. A strong excess of pairs is observed above the yield
expected from neutral meson decays. The unprecedented sample size of close
to 400K events and the good mass resolution of about 2% have made it possible
to isolate the excess by subtraction of the decay sources (keeping the ρ). The
shape of the resulting mass spectrum exhibits considerable broadening, but
essentially no shift in mass. The acceptance-corrected transverse-momentum
spectra have a shape atypical for radial flow and show a significant mass
dependence, pointing to different sources in different mass regions.
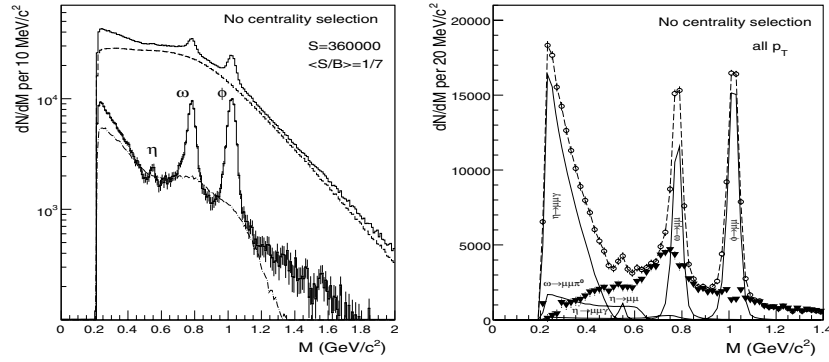
Figure 1. Left: mass spectra of the opposite-sign dimuons (upper histogram), combinatorial background (dashed), signal fake matches (dashed-dotted) and resulting signal (histogram with error bars). Right: isolation of an excess above the hadron decay cocktail. Total data (open circles), individual cocktail sources (solid), difference data (thick triangles), sum of cocktail sources and difference data (dashed).

1. Introduction

Thermal dilepton production in the mass region below 1 GeV/c^2 is largely mediated by the light vector mesons ρ, ω and ϕ. Among these, the ρ (770 MeV/c^2) is the most important, due to its strong coupling to the $\pi\pi$ channel and its short lifetime of only 1.3 fm/c. Changes both in width and in mass were originally suggested as precursor signatures of the chiral transition [1], and subsequent models have tied these changes directly [2] or indirectly [3] to chiral symmetry restoration.

The first NA60 results focused on the spacetime averaged spectral function of the ρ [4]; more details were added recently [5]. The present paper concentrates mainly on new developments, in particular first results on acceptance-corrected p_T and m_T spectra for different mass windows.

2. Experimental results

Details of the NA60 apparatus can be found in [6, 7], while the different analysis steps (including the critical assessment of the combinatorial background from π and K decays through event mixing) are described in [8]. The results reported here were obtained from the analysis of data taken in 2003 for In–In at 158 AGeV. The left part of figure 1 shows the opposite-sign, background and signal dimuon mass spectra, integrated over all collision centralities. After subtracting the combinatorial background and the signal fake matches, the resulting net spectrum contains about 360 000 muon pairs in the mass range 0–2 GeV/c^2, roughly 50% of the total available statistics. The associated average charged-particle multiplicity density measured by the vertex tracker is $\langle dN_{ch}/d\eta \rangle = 120$. The vector mesons ω and ϕ are completely resolved with a mass resolution at the ω of 20 MeV/c^2. Most of the analysis is done in four classes of collision centrality (defined through the charged-particle multiplicity density): peripheral (4−30), semiperipheral (30−110), semicentral (110−170) and central (170−240).

The peripheral data can essentially be described by the expected electromagnetic decays of the neutral mesons [4, 5]. This is not the case in the more central bins due to the presence
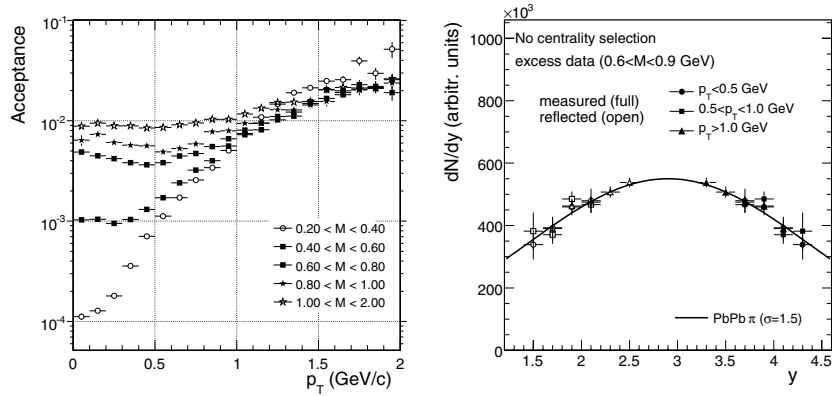
Figure 2. Left: acceptance relative to 4π for different mass windows. Right: rapidity distribution of the excess data for the mass window $0.6 < M < 0.9$ GeV/c^2 and for three selected p_T bins. The measured data (full markers) are reflected around midrapidity (open markers).

of a strong excess. To isolate this excess without any fits, a novel procedure has been devised [4, 5, 8]. The resulting spectrum for all centralities and all p_T shows a peaked structure residing on a broad continuum. The same feature can be seen for each centrality bin, with a yield strongly increasing with centrality, but remaining essentially centred around the position of the nominal ρ pole.

A more quantitative analysis of the shape of the excess mass spectra versus centrality has been performed, using a finer subdivision of the data into 12 centrality bins [5, 6]. On the basis of this analysis it is possible to rule out that the excess shape can be accounted for by the cocktail ρ residing on a broad continuum, independent of centrality.

A differential analysis in p_T was originally performed, and mass spectra associated with three different p_T windows, without acceptance correction, were obtained [5]. The NA60 acceptance relative to 4π as a function of p_T, as shown in figure 2(left), implies that one should in principle perform the acceptance correction using a three-dimensional grid in (M, p_T, y) space. This can lead, however, to large errors once the correction is applied. Instead, the correction is performed in two-dimensional (M, p_T) space, using the measured rapidity distribution as an input. The latter was determined with an acceptance correction found, in an iterative way, from Monte Carlo simulations matched to the data in M and p_T. On the basis of this rapidity distribution, 0.1 GeV/c^2 bins in M and 0.2 GeV/c bins in p_T were used to determine the remaining two-dimensional correction. After correction the results were integrated over the three extended mass windows $0.4 < M < 0.6$, $0.6 < M < 0.9$ and $1.0 < M < 1.4$ GeV/c^2. In figure 2(right) the rapidity distribution of the central mass window is shown for three different p_T windows, exhibiting a close resemblance to the distribution of inclusive pion production, as measured by NA49 for Pb–Pb and NA60 for In–In. The results for the acceptance-corrected p_T spectra are summarized in figure 3. The errors shown are purely statistical. Systematic errors arise from the acceptance corrections, including the rapidity distribution used, the subtraction of the cocktail, and the subtraction of the combinatorial background plus fake matches. For $p_T < 0.5$ GeV/c, the combinatorial background contributes most, ranging from 10 to 25% for semiperipheral up to central. For $p_T > 1$ GeV/c, the statistical errors dominate. The data show a significant dependence on mass, but hardly any on centrality. To bear out the differences in mass more clearly, the data
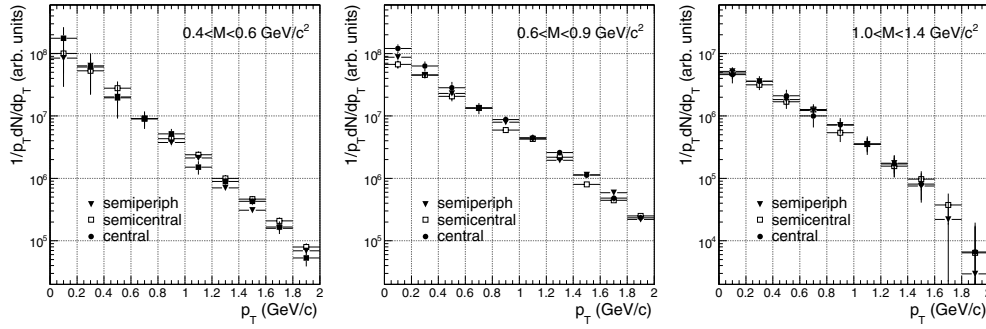
Figure 3. Acceptance-corrected p_T spectra for three mass windows and for three centrality bins. For discussion of errors, see the text.
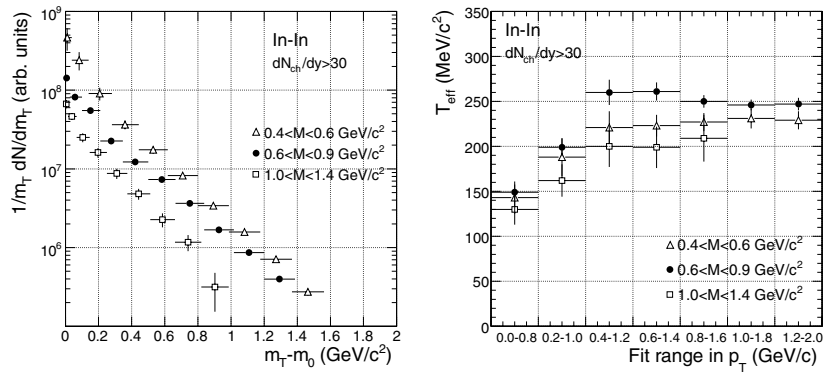
Figure 4. Left: acceptance-corrected m_T spectra for three mass windows, summed over centralities (excluding the peripheral bin). Right: inverse slope parameter T_{eff} from differential fits of the m_T spectra (see the text).

were summed over the three more central bins and plotted in figure 4(left) as a function of m_T. The inverse slope parameter T_{eff} as determined from differential fits of the m_T spectra with $\exp(-m_T/T_{eff})$, using a sliding window in p_T, is plotted on the right. Instead of flattening at very low m_T, as should be expected from radial flow, strikingly all spectra *steepen*, which is equivalent to very small values of T_{eff}. For comparison, the ϕ resonance, placed just in between the upper two mass windows, does flatten as expected. Moreover, depending on the fit region, T_{eff} covers an unusually large dynamic range. Finally, the largest masses have the steepest m_T spectrum, i.e. the smallest value of T_{eff} everywhere, again contrary to radial flow and to what is usually observed for hadrons. All this suggests that different mass regions are coupled to basically different emission sources. Summarizing, the previously measured excess mass spectra and the new acceptance-corrected p_T and m_T spectra present an unexpected behaviour. Beyond the ρ spectral function this may lead to a better understanding of the continuum part of the spectra for $M > 1$ GeV/c^2, possibly disentangling parton–hadron duality.

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